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Investigation of a Highway Bridge

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INVESTIGATION OF A HIGHWAY BRIDGE

BY

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I recommend that the thesis prepared under my supervision by EDWIN ARTHUR RANDALL entitled Investigation of a Highway Bridge be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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VIEWS OF GILBERT ST. BRIDGE

TABEL OF CONTENTS

An Investigation of the Gilbert St. Bridge

Part I

Introduction

Thorough bridge investigations are very necessary. Lack of them in many instances is very disastrous, not only jeopardizing human life and great amounts of public property, but also interfering with common carriers and general traffic. Bridges which have been erected for a considerable length of time should be either inspected or investigated quite frequently, for often times total rigidity may be affected by the replacement of a single weak member or joint with a new and more substantial one.

Because of the importance of this phase of bridge work, and the opportunity offered by it for a combin-

ction of an unusual highway bridge, an investigation of the "Gilbert St. Bridge," located at Danville, Illinois was chosen as the subject for this work. This investigation will embody a detailed description of the structure, including location; materials used; loading; calculated stresses; efficiencies; tables of weights of different spans; and a report upon its stability and present physical condition.

General Description

The Gilbert St. Bridge, as it is locally called, is a long, highway bridge spanning the Vermilion river, and is located about one-half mile west from the business district of the City of Danville Illinois. It extends almost due North and South and may be viewed in its entirety from the east. The view from the west is partially obstructed by trees and underbrush.

The entire structure is 1120 feet long and is made up of towers, deck

Pratt trusses and subdivided deck Warren trusses. The Warren trusses are used in the two main spans which are directly over the river, and for convenience these spans will be called "river spans."

<u>Floor System.</u> The total width of the bridge is 32 feet, consisting of a 22 foot roadway and two 5 foot walks, (one on either side). The floor beams which occur every 20 feet thru-out the length of the bridge, are 15" 50# I beams. Twelve 6"x16" long leaf pine joists, spaced two feet center to center, rest upon these beams. 3" flooring is laid diagonally upon these joists & nailed securely. One layer of heavy creosote paper covers the flooring and upon this paving blocks (size 8"x 4"x 3"), which have previously been treated by the creosote process, are laid. The filler used is a mixture of tar & creosote.

The sidewalks are raised six inches above the level of the roadway and consist of 2x6 inch

planks. About a quarter of an inch is allowed between planks to prevent their rotting. A fence made up of common gas pipe & small angles for posts, is on the outside of either side walk. There are five lines of pipe in all; four of $1\frac{3}{4}$ inch and one of $2\frac{3}{4}$ inch. The posts are 3"-4# channels and are placed every 10 feet. The side-walk is laid upon 4"x12" long-leaf pine joists which are supported by the ends of the floor beams which over-hang the trusses thus causing a cantilever action in the beams.

<u>Trusses</u> Two distinct types of trusses are used in this bridge, namely - Pratt & Warren. Both types are used as deck trusses; the Pratt trusses being used near the ends while the Warren trusses span the river. All are of the pin connected type and are made entirely from structural steel, large eye-bars being used in the main tension members, while built up members are used in compression. The lateral systems

and sway bracing are composed of square loop rods. All struts are built up with angles and lacing bars.

There are two lengths of the Pratt truss — the 3 panel, 60 foot, and the 4 panel, 80 foot. The depths are 12 and 16 feet respectively.

The Warren trusses are 270 and 280 feet long and 40 feet deep. These trusses are sub-divided in that they have built up verticals every 40 feet. Sub-diagonals consisting of square loop rods are also placed every 40 feet. Sag rods are used to support the lower chords. The unequal lengths of the Warren trusses is due to the fact that the river pier is skewed.

Towers. Built up towers are placed between the several Pratt trusses as a means of support for the "land" spans. There are four such towers, each being made up of two vertical bents which are longitudinally braced. The bents in turn are made up of "built up" members, the posts

being composed of four angles laced securely with single lattice bars. The batter of these towers is 2" in 12". The sway bracing is made up entirely of loop rods and the struts are composed of angles laced. Two single bents support the extreme ends.

The footings for these towers are made of stone masonry, blocks 4'x 4'x $1\frac{1}{2}$' being employed. These footings extend into the ground for some distance. The stones are laid in Portland cement mortar, joints being about 1 inch thick.

Piers. The two river spans are supported by three piers, two of which are built up approximately twenty feet above the surface of the ground. The third, which supports the south end of the south span is just level with the ground. The two former piers are made up of pitch faced ashlar masonry, the blocks of stone varying from 2'x 4'x $1\frac{1}{2}$' to 1'x 2'x 1'. The central pier (see photograph) is considerably skewed, being at an angle of about

65° instead of 90° with the axis of the bridge. This pier is 25' x 4' on top and has a batter of about 1 to 10 on two sides.

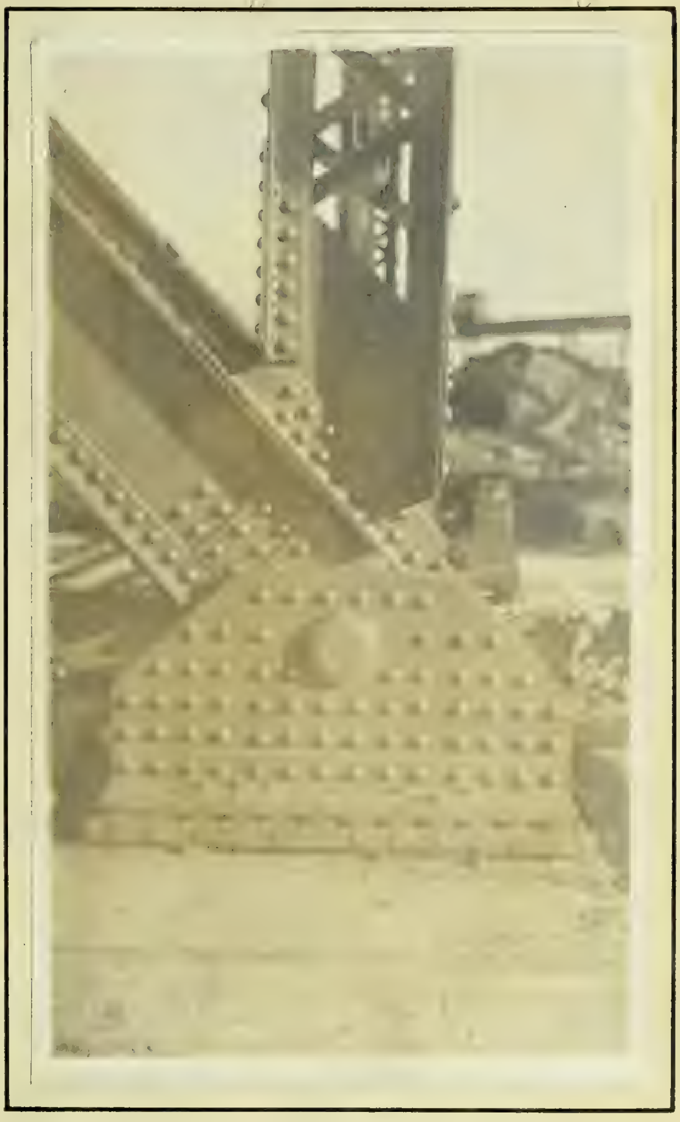
The south pier was replaced within the last year by two piers, one under the south end of each truss with the long dimension parallel to the bridge. These piers are made of rich concrete and are something over 16 feet deep. In the bottom of each is a grillage of 15" 90# I beams which rests directly upon bed-rock. This pier was rebuilt because of a settlement of $3\frac{1}{2}$ inches caused by heavy inter urban traffic which formerly crossed this bridge.

CENTRAL PIER

Upon these piers rest the ex-

pansion joints which are practically new. The rollers in each of these joints (12 in number) are 3 inches in diameter and 30 inches long. The old rollers, which are at present lying near the pier, apparently have never rolled since the erection of the bridge as they are clogged with dirt and rust in such a way as to appear like a solid mass.

The accompanying photograph gives an idea of the present expansion joint.



EXPANSION JOINT

Abutments.

The masonry in the two abutments is of the same general character as that of the piers. They are of the straight-

wing type and are about 20 feet high. The thickness at the top is $3\frac{1}{2}$ feet, 2 feet of which is bearing area for the end joists.

Part II

Stresses and Efficiencies

Dead and live load stresses were computed in all of the members of both trusses as well as in the different parts of the floor system and wind bracing. The live loads used in these computations were those which are recommended in the 1909 edition of "Cooper's Specifications". The dead loads are those which were computed from the weights of the floor system and trusses as found by actual measurement.

The efficiencies were computed by taking the ratio of the area required by both live and dead load stresses to the actual areas of the members in the bridge.

River Span

Warren Truss. (See photograph)

The live loading for this truss was secured from Table A in

SKEW PANEL IN WARREN TRUSS

the specifications under Class A bridges. The dead load was computed from the weights given in Table A.

Table A
Weights of Flooring and Warren Truss

1st Panel	22950#
2nd Panel	23000
3rd Panel	19700
Sub-Panel	9800
Sway & Wind Bracing	15150
One half Floor System	177500
Main Verticals	13000
Total	281,100#

The total dead load upon the truss is 281,100.# making a load of 20,000# on each of 14 panels. The dead and live load stresses may be found in Table B. sheet 16, along with the section of each member. The efficiencies are placed on the members in Fig. 1 sheet 13.

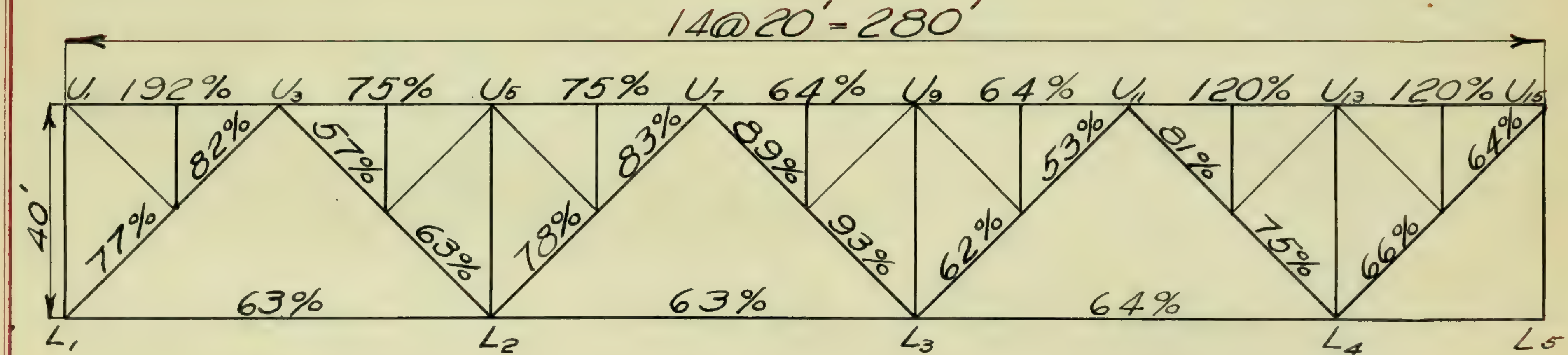
Altho the bridge at present has no electric car tracks, its location warrants the consideration of a double track in the investigation, thereby placing it in Class A_2

Pedestal.

A 4 inch pin rests upon 6 plates each one half inch thick. (3 at either end). The actual bearing area is 12 sq. inches. The required bearing area is 16.66 sq. inches as total reaction is 338000#. The efficiency is 72.5%.

Rollers. (See photograph in Part I)

The south end of the truss rests upon a nest of 12 - 3" x 30" rollers. The efficiency is 76% in bearing. The rollers are not large enough for this size span as they should have a diameter of $5\frac{1}{4}$ inches. (See spec. Art 127)



Efficiency of Verticals = 78%
Efficiency of Sub Verticals = 103%
Efficiency of Sub Diagonals = 68%

Dead Panel Load = 20.0
Live Panel Load = 32.0

14 PANEL WARREN TRUSS

Class A_2

Fig. 1

There are no hinged bolsters at either end.

End Struts and Bracing.

450# per linear foot of truss due to wind was assumed in computing the efficiencies in the end struts. (See Art. 39) These efficiencies are shown on Fig. 2, sheet 15.

Intermediate Struts.

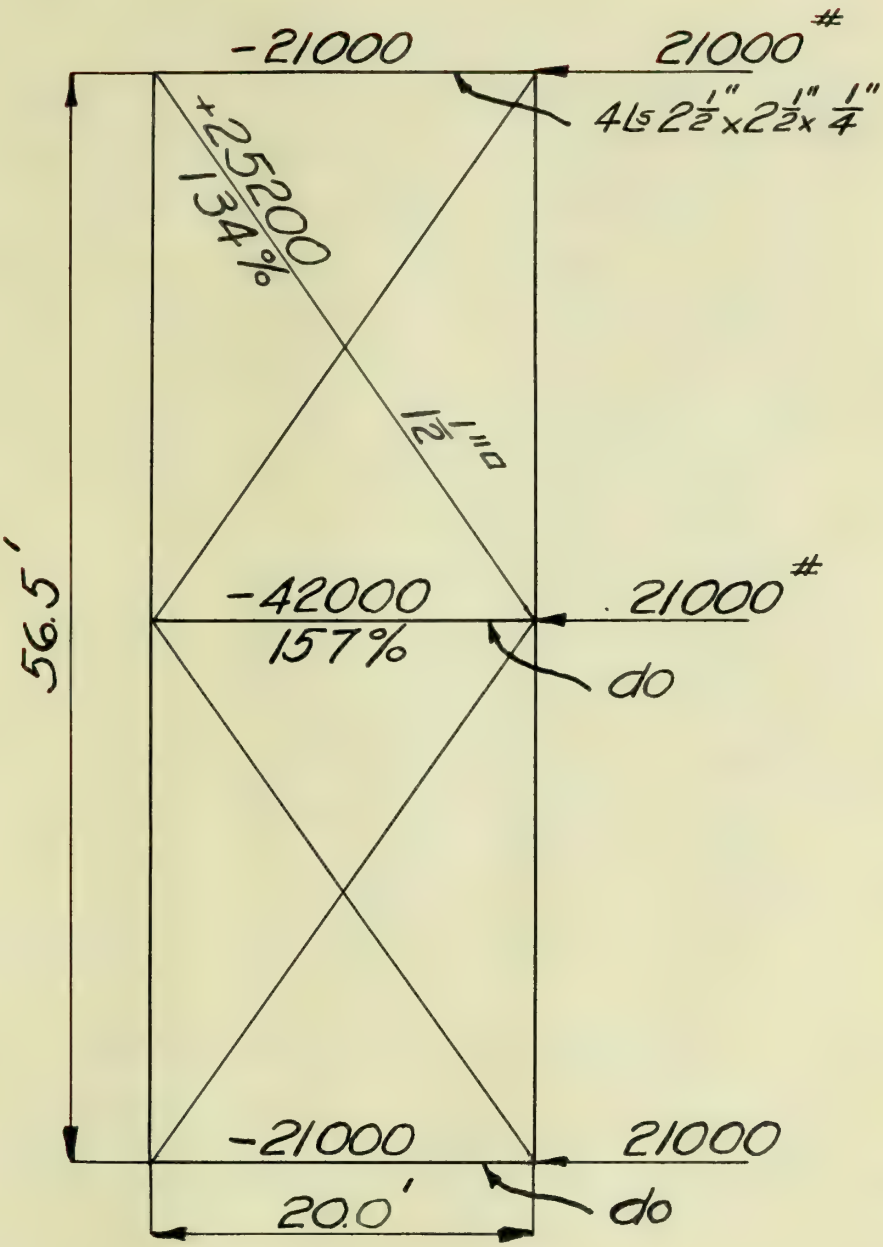
These struts are used to brace the trusses at the points where the sub-verticals and web-members join. They resist one half the wind load which comes upon the web-member to the amount of 50# per linear foot, making a total stress of 1909# in each strut. The efficiency is 1300%

Laterals.

All laterals and sway bracing are sufficient to carry what wind load comes upon them.

Joints.

All joints are pin-connected; $\frac{3}{4}$" rivets are used in the connection plates of all main members;



END STRUT (PORTAL)

Fig 2

Table B
Stresses and Sections in Warren Truss

	Member	Dead	M. Live	m. Live	Max.	Min	Section
Webs	$L_1 m_1$	-169.0	-270.0	0.0	-439.0	-169.0	Angles Plates
	$m_1 U_3$	-156.0	-252.0	+3.2	-408.0	-152.8	"
	$U_3 m_2$	+127.5	+214.0	-9.6	+341.5	+117.9	2 Eye-bars
	$m_2 L_2$	+113.5	+190.0	-9.6	+303.5	+103.0	"
	$L_2 m_3$	-56.6	-123.0	+33.0	-179.6	-23.6	Laced Angles
	$m_3 U_7$	-42.4	-116.0	+49.0	-158.4	+6.6*	"
	$U_7 m_4$	+14.1	+90.5	-68.0	+104.6	-53.9*	"
	$m_4 L_3$	0.0	+68.0	-68.0	+68.0	-68.0*	"
	$L_3 m_5$	+56.6	-32.0	+123.0	+179.6	+24.6	2 Eye-bars
	$m_5 U_{11}$	+70.7	-32.0	+146.0	+216.7	+38.7	"
	$U_{11} m_6$	-99.0	+19.2	-178.0	-277.0	-79.8	Laced Angles
	$m_6 L_4$	-113.5	+9.6	-191.5	-305.0	-103.9	"
	$L_4 m_7$	+170.0	0.0	+272.0	+442.0	+170.0	2 Eye bars
	$m_7 U_{15}$	+184.0	0.0	+272.0	+456.0	+184.0	"
L. Chord	$L_1 L_2$	+120.0	+192.0	0.0	+312.0	+120.0	2 Eyebars
	$L_2 L_3$	+240.0	+384.0	0.0	+624.0	+240.0	4 Eye bars
	$L_3 L_4$	+200.0	+320.0	0.0	+520.0	+200.0	2 Eyebars
	$L_4 L_5$	0.0	0.0	0.0	0.0	0.0	Laced Angles
U. Chord	$U_1 U_3$	-10.0	-16.0	0.0	-26.0	-10.0	Laced Angles.
	$U_3 U_5$	-210.0	-336.0	0.0	-546.0	-210.0	Angles and Plates
	$U_5 U_7$	-210.0	-336.0	0.0	-546.0	-210.0	"
	$U_7 U_9$	-250.0	-400.0	0.0	-650.0	-250.0	"

Table B (Con.)

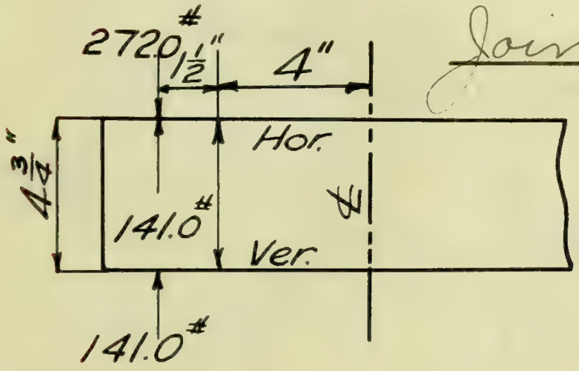
U. Chord U_9U_{11}	-250.0	-400.0	0.0	-650.0	-250.0	Angles and Plates
$U_{11}U_{13}$	-130.0	-208.0	0.0	-338.0	-130.0	"
$U_{13}U_{15}$	-130.0	-208.0	0.0	-338.0	-130.0	"
Verticals all alike	-40.0	-64.0	0.0	-104.0	-40.0	Angles laced.
Sub. Ver. all alike	-20.0	-32.0	0.0	-52.0	-20.0	Channels laced
Sub. Diag. all alike	+14.3	+23.0	0.0	+37.3	+14.3	Square Loop Rods

* Reversal.

and $\frac{5}{8}$" in those of the struts.

As the joints at U_3 and L_2 are under the heaviest strain, they were figured in detail. Efficiencies in pins were figured considering maximum stresses acting in all members at the same time.

Joint at U_3



Pin U_3

Max. B. M. = 288000 "#

Efficiency = 73%

Riveting in U_3

46 Rivets used in built up web.

Eff. (Shear) 81%

Eff. (Bearing) 124%

Eff. (Bearing on Pin) 51%

JOINT AT L_2

Joint at L_2

(See Photograph)

Riveting in L_2

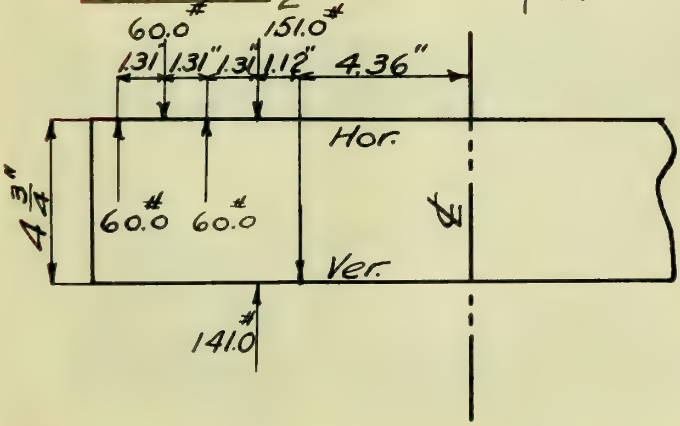
28 Rivets used in built up web.

Eff. (Shear) 81%

Eff. (Bearing) 96%

Eff. (Bearing on Pin) 50%

Pin L_2



Max. B.M. = 184,000"#

Efficiency = 114%

Minor Span

Pratt Truss (See Photograph.)

The live loading for the 80 foot Pratt truss was secured from Table A in the specifications, as was that of the Warren truss. The dead panel load was considered as 18000,# the total weight of truss and one half of floor system being 71,000.# For separate weights see Table C sheet 20. Stresses for each member along with its section may be found in Table D sheet 20. The efficiencies are placed upon the separate members in Figure 3 sheet 21.

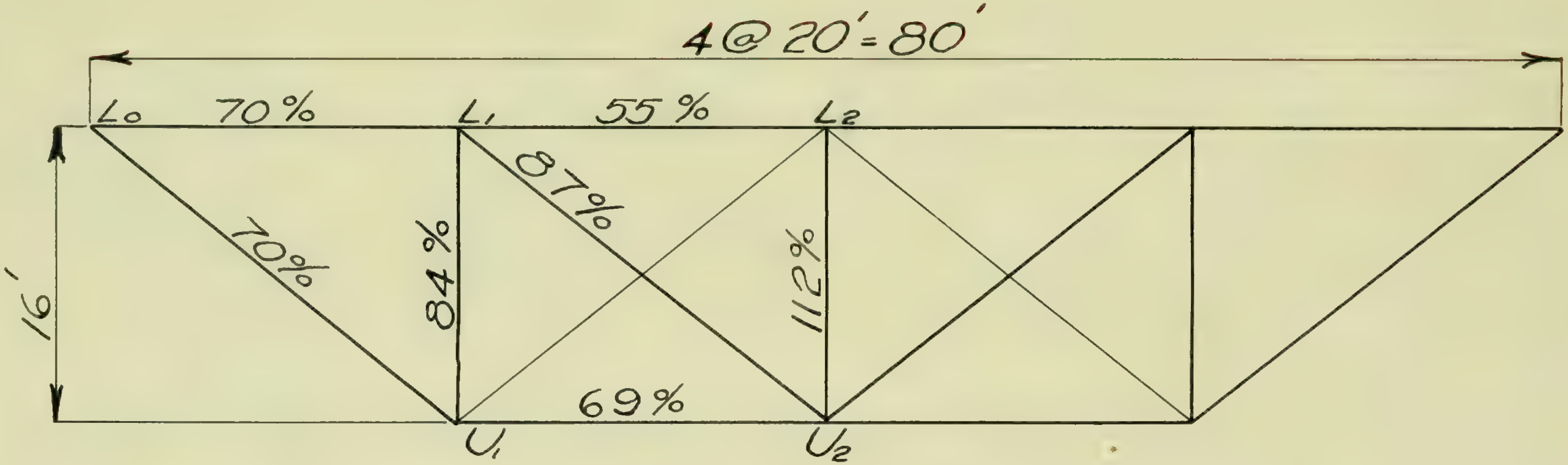
FOUR-PANEL PRATT TRUSS

Table C
Weights of Floor System and Pratt Truss (per panel).

Roadway-flooring	11900#
Roadway Joists	8350
Floor Beams	1635
Side-walk-flooring	2160
Side-walk Joists	3240
Water Pipe (hand-rail)	650
Total floor system	27,935#
Load on 1 Truss ($\frac{1}{2}$ Floor system)	13,967#
$\frac{1}{2}$ Lateral Bracing	1,500
Av. Weight of steel in Panel	[illegible]
Total Panel Load	17,367#

Table D
Stresses and Sections in Pratt Truss

	Member	Dead	Max. Live	Max.	Section
Web	L_0U_1	+43.1	+86.2	+129.3	2 Eye bars
	L_1U_1	-27.0	-54.0	-81.0	Channels laced
	L_1U_2	+14.4	+43.2	+57.6	2 Eye bars
	L_2U_2	-18.0	-36.0	-54.0	Channels laced
L. Chord	U_1U_2	+33.6	+67.2	+100.8	2 Eye bars
U. Chord	L_0L_1	-33.6	-67.2	-100.8	Plates + Channels
	L_1L_2	-45.0	-90.0	-135.0	" "



Dead Panel Load = 18.0
Live Panel Load = 36.0

4 PANEL PRATT TRUSS

Class A_2

Fig. 3

Floor System

The entire floor system was investigated for both uniform and concentrated loadings. (See Art. 38.)

Joists.

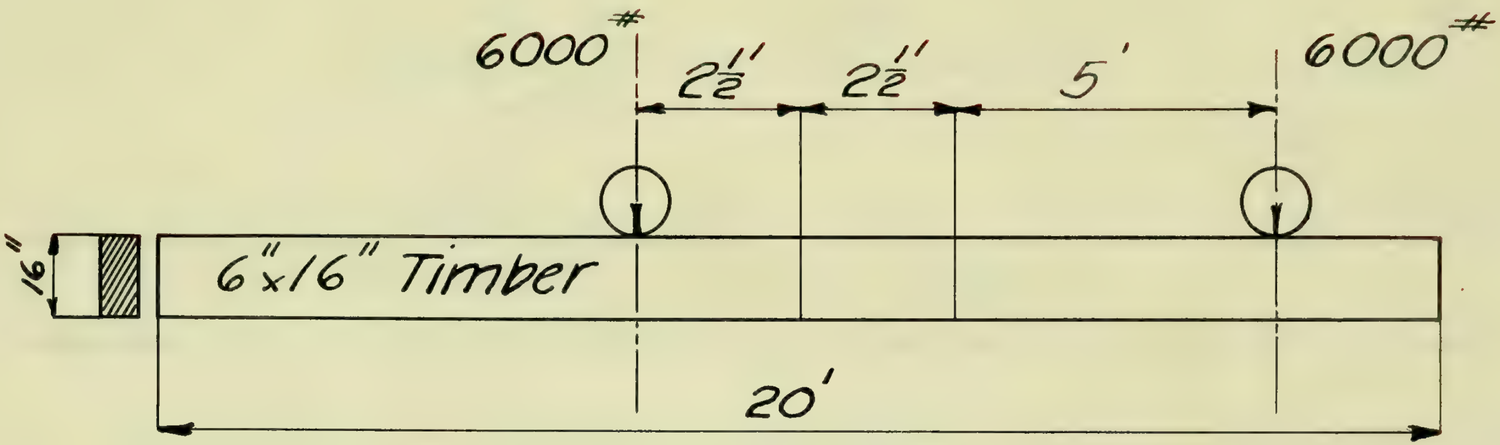
The dead load bending moment at the critical section is 46,000"# and the maximum live load bending moment is 405,000"# making a total of 451,000."# The arrangement of loading and the efficiency of joist is shown on Figure 4, sheet 23.

Floor Beams.

The maximum bending moment in the beam is 224,400."# The arrangement of loading and the efficiency of I beam is shown on Figure 5 sheet 24.

Tower Span

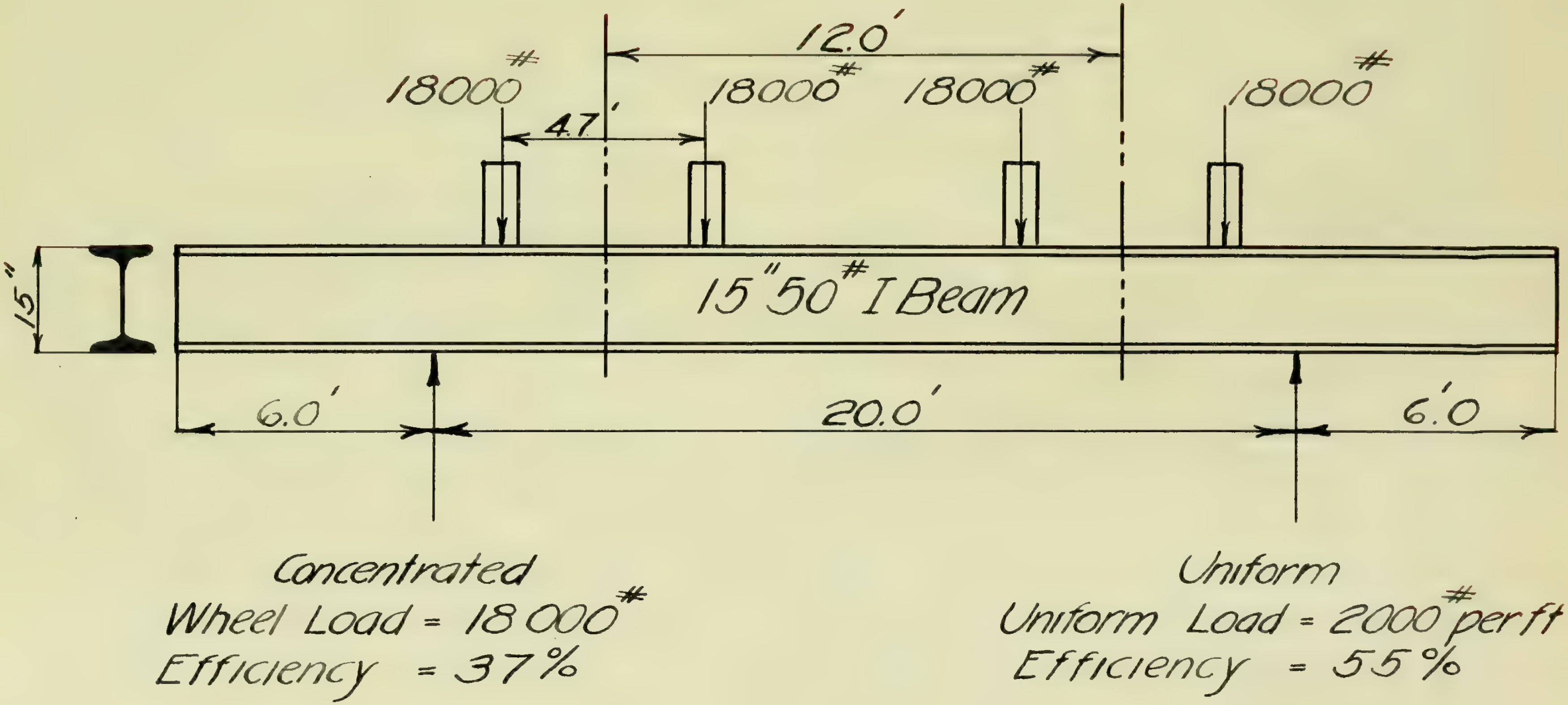
The tower span, as was stated in the general description is just 20 feet long and is made up of two trestle bents braced both longitudinally and trans-



Wheel Load = 12000#
Load on 1 Joist = 6000#
Efficiency = 68%

JOIST

Fig. 4



FLOOR BEAM

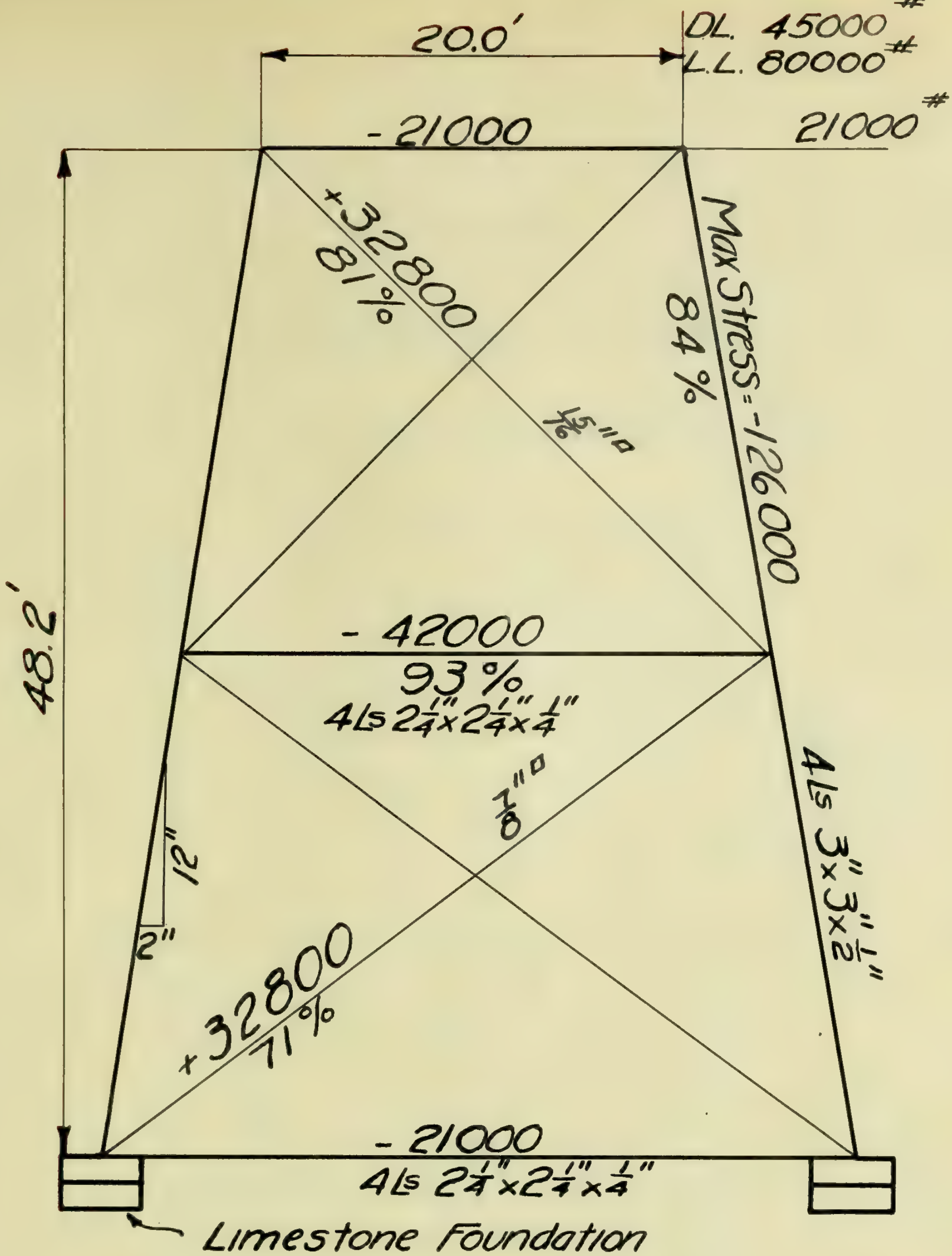
Fig. 5

versely. The bracing consisting mainly of built up members, is so placed as to insure rigidity in this span. As tractive resistance can-not be accurately figured in a high-way bridge, numerical efficiencies will only be given in the posts. The tower which was investigated in detail is the first one north of the "river spans" and because of its height and location was considered most important. The south trestle bent in this tower takes the reaction of a 4 panel Pratt truss.

Trestle Bent.

The total stress coming into each post of this bent is 126,000#, 45400# being due to dead load reaction and 80,600# due to live load reaction. The wind load stress is 25,100 which is less than 30% of sum of live and dead load stresses. Therefore it is not considered in the efficiency.

For stresses and efficiencies see Figure 6 sheet 26.



TRESTLE BENT

Fig 6

Part III

Physical Condition and Recommendations

Warren Truss

A. Main members.

1. Tension. All eyebars are in good condition. They are well painted and the section has not been decreased by corrosion. No change is recommended.

2. Compression. The plates in the built up members are somewhat rusted on the inner face. As yet the corrosion is not sufficient to permit of its measurement. Such plates should have two coats of good quality iron ore paint, mixed with pure linseed oil. (See Art. 169)

The deformed lattice bars in member $L_1 U_3$ should be replaced by new ones. These

bars should be well painted as stated in Art. 169, (Spec.)

B. Struts

In all the struts which brace the end web members, and which consist of 4 angles laced, there is a "trough angle." In every instance this angle is corroded to such an extent that it has practically no effective section. In the extreme cases, one might run his finger directly thru the angle. Such angles should be replaced by new ones of same section as that of the old. Strut connections seem to be in very good condition.

C. Laterals and Sway Bracing.

The steel in all rods used for bracing is in good condition. However, all rods having turn-buckles should be tightened.

D. Riveting.

All riveting in connections

is sufficient, that is, efficiency of joints is greater than that of members.

E. Pedestals

The pedestals and expansion joints in the south "River Span" are new, having been replaced within the last year. Those in the north "River Span" should be replaced. The rollers should be inspected, and, if necessary cleaned at least twice a year.

F. Joints.

The pins have started to corrode. In some cases the rings have rusted off. These should be replaced. All joints should be given two coats of good paint. (See Art. 67)

Pratt Truss.

A. Main Members.

1. Tension. Physical condition is good. No change is recommended.
2. Compression. Upper chord

in second panel should be increased by 40% of its own section, to bring its efficiency up to the average. This section may be increased by riveting reinforcing plates to the web of the channel.

B. Struts.
All struts are satisfactory

C. Laterals and Sway Bracing.
No change is recommended.

D. Joints
All upper chord joints should be reinforced with $\frac{1}{2}$ inch pin plates. All riveted joints should have two coats of good quality paint.

Floor System

A. Joists.
All joists are sound, long-leaf, pine timbers. They are unpainted. It is recommended that two coats be applied.

B. <u>Floor Beams</u>
Because of their extremely low efficiency, it is recommended that these 15"-50# I beams be replaced by 15"-70# I beams

C. <u>Flooring</u>
The entire flooring was newly laid 6 months ago and is in excellent condition. This also should be painted on the under side.

<u>Trestle Bents</u>

A. <u>Posts</u>
Posts are well painted and in good condition.

B. <u>Bracing</u>
Lower braces are considerably rusted. They also do not seem rigid enough, considering their length. It is recommended that they be replaced by members which consist of 4 angles $2\frac{1}{2}" \times 2\frac{1}{2}" \times \frac{3}{8}"$ laced.

Foundations

A. Piers

All piers are satisfactory. Pressure area is sufficient. Joints are well preserved. Some of the blocks in the skewed pier are burrowed into, but not to such an extent as would be harmful.

The pier supporting the expansion joint is new and in excellent condition.

B. Tower Supports

Joints in several of these supports need pointing, with this exception the foundations are satisfactory.

Summary

From the efficiencies obtained in all members and parts of bridge - it is evident that the structure was not designed for load-

ing used in Class A_2. As the efficiencies in general range from 70 to 80% no loads should ever be allowed upon the bridge to exceed 70% of those used in this investigation.

The trusses as they are now could not safely carry electric or suburban cars. As the joists are of wood they also would be insufficient.

Teamsters with heavy loads must be required to drive slowly across the bridge. The vibrations caused by a horse moving at a trot are great, and should many teams move swiftly and in rhythm across the bridge, they might prove very disastrous.

The physical condition as a whole is good - lateral struts being the only members that require renewals because of corrosion. The cause of this rotting, as it literally is, may be laid to water

and droppings from the floor above. In many cases the trough angle was nearly filled with dirt etc. In view of the fact that the present floor is tight and approximately water proof, no further trouble may be expected along this line.

Taking the general physical condition of the bridge as well as its location into consideration - I cannot condemn the bridge and recommend that it be torn down. It may be used safely as a simple high-way bridge, but should it become necessary to place tracks upon it, previous reinforcement must be required.

End.